Appendix A Supporting Information on Uncertainties in Traffic Data and Rationale for Roadway Design Considerations

A.1 Uncertainties in Traffic Data

Uncertainties exist in the data collected for the HPMS and Traffic Demand Modeling applications that should be recognized when interpreting this data to identify suitable road segments for NO_2 near road NAAQS monitoring. These uncertainties relate to the type and frequency of traffic data collected, location of sampling, and the characterization of vehicle type with these systems.

A.1.1 Measurement and Frequency Uncertainties

Measurement types include fixed, automated sensors and temporary devices that can be deployed for short periods of time on a given road section. Data collected during relatively short duration campaigns can sometimes be used to represent longer periods of time, such as annual averages.

A.1.2 Fixed Measurement Systems

Automated traffic recorders and weigh-in-motion devices comprise the options available for fixed, long-term measurements of traffic volume. These sampling devices typically operate for over a year, so these measurements can be directly related to an AADT value.

A.1.3 Temporary Measurement Systems

Pneumatic tubes can be used for short-term measurements of traffic volumes. When these devices are used for traffic measurements, expansion factors must be used to estimate AADT volumes on that road segment. These expansion factors can be related to maximum hourly traffic volumes or the overall number of days of sampling conducted with the temporary devices.

A.1.4 Sampling Location Uncertainties

Since resource restrictions do not allow for the siting of traffic counting devices at all locations, there are uncertainties associated with the estimation of traffic volumes along roadway segments not monitored.

A.1.5 Vehicle Characterization Uncertainties

The measurement devices described above have limitations in differentiating the mix of vehicles present on the roadway. Many devices separate light-duty from heavy-duty vehicles using length factors. These lengths can be misclassified due to a number of factors including tailgating and multiple truck axles, although misclassification depends on the measurement device. In addition, these devices cannot differentiate between vehicles operating on gasoline versus diesel fuels. While this differentiation is not critical for highway planning, understanding the distribution of gasoline versus diesel vehicles can be very important for emissions and air quality characterization. In the United States, the vast majority of light-duty vehicles (less than 20 feet in length) operate on gasoline, while the vast majority of heavy-duty vehicles (greater than 40 feet in length) operate on diesel fuel. Medium-duty vehicles (between 20 and 40 feet in length) can operate on either gasoline or diesel fuels, and present the highest uncertainties related to air pollutant emissions and fuel use.

Appendix B Using MOVES to Create a Heavy-Duty to Light-Duty NO_x Emission Ratio for Use in this TAD

As described in Section 6, the HD_m ratio of 10 was chosen to weight the contribution of heavy-duty vehicle emissions compared with emission rates from light-duty vehicles for use in creating FE-AADT values. This ratio was chosen using national default emission values for both heavy- and light-duty vehicles, and represents a realistic ratio of average heavy-duty to light-duty vehicle emissions nationally for typical highway driving conditions. Actual emission rates can vary based on a number of factors including the vehicle technology, fuel burned, vehicle speed, vehicle load, and ambient temperature. Thus, a single HD_m value cannot capture all of the variability that can be experienced among differing vehicle types. There may be situations under which a state may choose to calculate a local HD_m value or local values based on information for a specific road segment or for a particular season, as discussed in more detail in Section 7.

Table B-1 lists average motor vehicle emission rates using national default values of fleet distribution and speed for the year 2010 as provided by EPA's Office of Transportation and Air Quality (OTAQ) running the MOVES emissions model. The year 2010 was chosen based on the likely year of traffic data available to state and local air agencies during the initial process of identifying candidate sites. Note that these emission factors represent hot, stabilized running conditions only; cold starts are not included since these events are unlikely to occur during highway or other high volume roadway driving activities. In addition, the default temperature and humidity used to calculate this ratio for January and July represented national averages. As shown in this table, an HD_m value of 10 provides a representative approximation of the heavy-duty to light-duty vehicle emissions ratio using national default values. A simplified HD_m factor of 10 signifies a ratio of a combination of heavy-duty and light-duty vehicles commonly found on US highways at typical highway operating speeds.

Table B-1. Average motor vehicle emissions rates within two seasonally representative months using national default values of fleet distribution and speed for 2010.

Month	Vehicle Type	NOx Emission Rate (g/mile)	HDm Ratio
January	Heavy Duty	10.09	10.96
	Light Duty	0.92	
July	Heavy Duty	8.47	9.33
	Light Duty	0.91	

For areas that have data on road segment congestion or fleet mix, more detailed assessment can be made using MOVES emissions results. **Figure B-1** and **Figure B-2** provide examples of how emission rates vary by vehicle speed and type. These graphs compare emission rates for vehicles commonly using US highways with separate graphs provided for January and July of 2010 (to highlight emission differences between warmer and colder ambient temperatures). As shown, the ratio of emissions can vary widely among vehicle types and speeds.

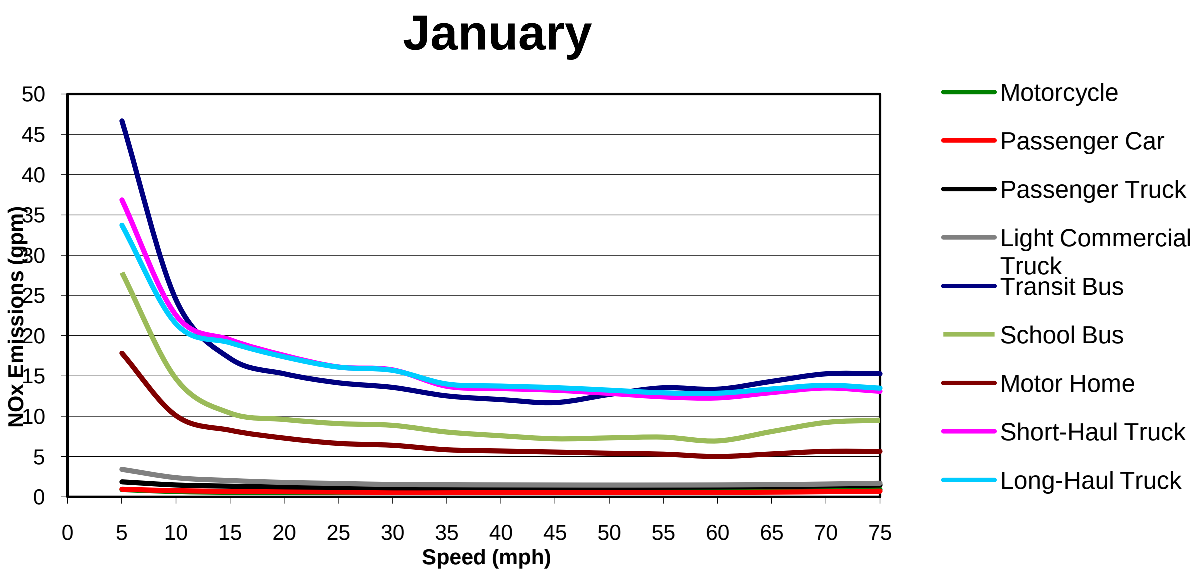

Figure B-1. Average NO_x emission rates by vehicle type and speed for January, 2010.

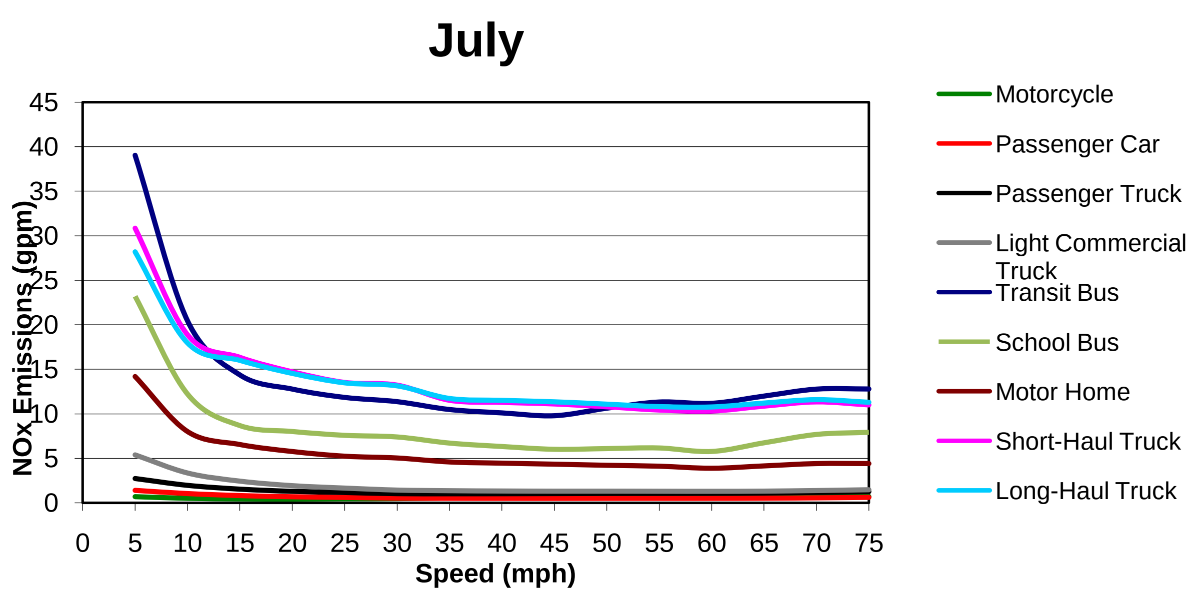

Figure B-2. Average NO_x emission rates by vehicle type and speed for July, 2010.

Appendix C Modeling

This appendix offers specific guidance to those state and local agencies choosing to use modeling to further inform the implementation of near-road NO_2 monitors. This appendix offers guidance on the selection of an air quality model, modeling domain (including receptor placement), characterization of emission sources, meteorological inputs, and inclusion of background concentrations.

C.1 Guidance on Air Emissions Models

The following sections provide an overview of using MOVES for project-level analyses[1]. This guidance is based on

1. the MOVES User Guide (U.S. Environmental Protection Agency, 2010a),
2. Section 4 of EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas* (U.S. Environmental Protection Agency, 2010b), and
3. EPA's "Using MOVES in Project-Level Carbon Monoxide Analyses" [2](U.S. Environmental Protection Agency, 2010c).

Interested agencies should consult these documents for further details when performing MOVES project-level analyses.[3] For guidance documents, see http://www.epa.gov/otaq/stateresources/transconf/policy.htm#project.

---

[1] This appendix uses "MOVES" to refer generically to any approved version of the MOVES model. This guidance is applicable to current and future versions of the MOVES model, unless EPA notes otherwise.

[2] For the user guide, see: http://www.epa.gov/otaq/models/moves/index.htm#user; other guidance documents are available at http://www.epa.gov/otaq/models/moves/index.htm. For guidance documents, see http://www.epa.gov/otaq/stateresources/transconf/policy.htm#project.

C.1.1 Geographic Scale of Analysis

MOVES can be used to model emissions for different geographic scales. For analyzing individual road segments, the "Project" scale of MOVES should be employed. The "County" and "National" scales are not suitable for analyzing individual road segments. See Section C.1.3for further information on specifying the Project scale in a MOVES "Run Specification."

At the Project scale, MOVES represents emissions of a particular roadway as a series of "links." The purpose of defining a roadway as one or more MOVES links is to accurately capture emissions where they occur. Generally, links specified for a roadway should include segments with similar traffic characteristics and vehicle activity. Using link-specific vehicle activity and other inputs, MOVES calculates emissions from every link of a project for a given hour. There are no limits to the number of links that can be defined in MOVES.

The Project scale allows the user to enter data that applies to the project being analyzed through the Project Data Manager. Modeling to support siting of near-road NO_2 monitors should incorporate the most recently available data. MOVES also includes a default database of meteorology, fleet, activity, fuel, and control program data for the entire U.S. The information in

---

[3] Note that these technical guidance documents were developed to address other requirements. However, certain sections of the guidance may be applicable when completing analyses of transportation projects for other purposes, such as when completing NO_2 modeling as described in this appendix.

the default database comes from a variety of sources which may not necessarily be the most accurate or up-to-date information available. For some needed inputs, such as fuel information, it may be appropriate to use the national defaults.

C.1.2 Time Period of Analysis

When MOVES is run at the Project scale, it estimates emissions for only the hour specified by the user. State and local agencies may have activity data collected over a range of possible temporal resolutions. Multiple MOVES runs can be completed to represent emissions during different time periods. In most cases, traffic data will represent weekdays, which should be so indicated in MOVES. The year, month, and hour should be defined for each MOVES run. Since modeling will be used to compare potential impacts at multiple sites, it is important that the same modeling years are evaluated for each road segment.

C.1.3 Developing a MOVES Run Specification (RunSpec)

A MOVES RunSpec is a computer file in XML format that can be edited and executed directly or with the MOVES Graphical User Interface (GUI). MOVES needs the user to set up a RunSpec to define the place and time of the analysis as well as the vehicle types, road types, fuel types, and the emissions-producing processes and pollutants that will be included in the analysis.

A RunSpec is entered through the Navigation Panel of the MOVES GUI. To create a project-level RunSpec, a user moves through the relevant tabs and fills in data appropriate for each item listed:

- *Description* – The user may enter up to 5,000 characters of text.
- *Scale* – The user must specify the “Project” scale. In this panel, the user also should select output as “Inventory” (grams per hour per link) if using AERMOD to complete the air quality modeling.

- *Time Spans* – Here, the user specifies the hour, day, month, and year. Also, the user specifies time aggregation (select "hour" for analysis of individual road links).
- *Geographic Bounds* – The user defines the county being modeled. County information in MOVES determines some default information in the analysis.
- *Vehicles/Equipment* – This panel is used to specify the vehicle and fuel types to be included. MOVES includes 13 "source use types," such as "passenger car" and "long-haul combination truck."
- *Road Type* – This panel defines the types of roads included in the run. Road types determine which default vehicle driving cycles MOVES assigns to vehicles. In most scenarios evaluated for NO_2 near-road monitoring, the urban restricted access road type will be used, although a state or local agency may be interested in comparing impacts from other road types and segments.
- *Pollutants and Processes* – This panel identifies the pollutants and emission processes to be calculated by MOVES. For NO_2 modeling, the user should identify "Oxides of Nitrogen," "Nitrogen Oxide," and "Nitrogen Dioxide." "Running Exhaust" and "Crankcase Running" emission processes should be selected for modeling individual road links.[4]
- *Manage Input Data Sets* – This panel is not used in most project-level analyses. The Project Data Manager is used for creating input databases.
- *Strategies* – This panel can be used to model alternative control strategies that affect the composition of the vehicle fleet. In most situations, the state or local agency should use

[4] If other transportation facilities are evaluated (e.g., diesel truck or bus activity at terminals), then additional emission processes would be considered in MOVES.

the same strategies for all road segments analyzed unless existing information is known regarding a difference in applicable strategies among different road segments.

- *Output* – This panel is used to specify output formats. Under "General Output" users should select "grams", "miles", and "joules" for output units, and "Distance Traveled" and "Population" to obtain vehicle volume information for each link modeled and to provide details for evaluating MOVES results. Under "Output Emissions Detail," emissions by hour and link are required for use in AERMOD.
- *Advanced Performance Features* – This panel is not used in most project-level analyses.

C.1.4 Entering Project Details Using the Project Data Manager

Once the choices for establishing a RunSpec have been set, the user should create appropriate input databases using the Project Data Manager, which can be accessed from the Pre-Processing menu item on the menu bar on top of the GUI. The Project Data Manager has a series of tabs through which site-specific data is entered:

- *Links* – MOVES represents individual road segments as "links." This importer is used to define individual road links, which must be assigned a unique ID. This importer requires information on the link's length, traffic volume, average speed, and road grade.
- *Link Source Type* – Users enter the fraction of link's traffic volume represented by each vehicle type (source type).
- *Link Drive Schedule* – An optional importer that imports a 1-second time series driving trace (speed and road grade) intended to represent vehicle driving behavior on the road link modeled.
- *Operating Mode Distribution* – Users specify the distribution of operating modes for source types, hour/day combinations, roadway links, and pollutant/process combinations

that are included in the run specification. This importer is considered an advanced option that requires detailed vehicle activity data, and is typically not used.

- *Off-Network* – Users specify vehicle populations and activity for locations where vehicles park, start, and/or idle for extended periods of time, such as parking lots or truck stops.
- *Age Distribution* – Used to enter information on the distribution of vehicle ages (ageID) within the calendar year and vehicle type.
- *Fuel Supply and Fuel Formulation* – Used to provide fuels and fuel mix in the area modeled. These inputs should generally be the same for all road segments in an area.
- *Meteorology* – Used to specify temperature and humidity data for the month and hour modeled in the MOVES RunSpec.
- *Inspection and Maintenance* – In general, inspection and maintenance (I/M) programs apply to vehicle fleets throughout certain nonattainment and maintenance areas.

C.1.5 MOVES Output Format

MOVES produces an output database that contains a line for each year, hour, link, pollutant, process, fuel, and model year (if selected). MOVES produces either "inventories" (mass emissions per hour) or emission rates. Inventory output can be used in AERMOD directly (with additional source characterization as described below). MOVES emission rates must be post-processed to obtain emission rates suitable for use in AERMOD.

C.2 Guidance on Air Quality Models

This guidance is based on and is consistent with EPA's *Guideline on Air Quality Models*, also published as Appendix W of 40 CFR Part 51 (U.S. Environmental Protection Agency, 1993; U. S. Environmental Protection Agency, 2005). Appendix W is the primary source of information on the regulatory application of air quality models for State Implementation Plan

(SIP) revisions for existing sources and for New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs. Air quality modeling to inform the implementation of NO_2 near-road monitors would need to employ air quality dispersion models[5] that properly address NO_2 emissions and, thus, should rely upon the principles and techniques in Appendix W.

Appendix W was originally published in April 1978 and was incorporated by reference in the regulations for the Prevention of Significant Deterioration of Air Quality, Title 40, Code of Federal Regulations (CFR) sections 51.166 and 52.21 in June 1978 [43 FR 26382-26388]. The purpose of Appendix W guidelines is to promote consistency in the use of modeling within the air quality management process. These guidelines are periodically revised to ensure that new model developments or expanded regulatory requirements are incorporated.

Clarifications and interpretations of modeling procedures become official EPA guidance through several courses of action:

(1) the procedures are published as regulations or guidelines;

(2) the procedures are formally transmitted as guidance to Regional Office managers;

(3) the procedures are formally transmitted as guidance to Regional Modeling Contacts as a result of a Regional consensus on technical issues; or

(4) the procedures are a result of decisions by the EPA's Model Clearinghouse that effectively establish national precedent.

Formally located in the Air Quality Modeling Group (AQMG) of EPA's Office of Air Quality Planning and Standards (OAQPS), the Model Clearinghouse is the single EPA focal

[5] Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations.

point for the review of criteria pollutant modeling techniques for specific regulatory applications. Model Clearinghouse and related Clarification memoranda involving decisions with respect to interpretation of modeling guidance are available at the Support Center for Regulatory Atmospheric Modeling (SCRAM) website.[6]

Recently issued EPA guidance of relevance for consideration in modeling for attainment and maintenance demonstrations includes

- "Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS" June 28, 2010—confirming that Appendix W guidance is applicable for NSR/PSD permit modeling for the new NO_2 NAAQS (U.S. Environmental Protection Agency, 2010d).
- "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" March 1, 2011– provides additional guidance regarding NO_2 permit modeling and also relevant to modeling for implementation of NO_2 near-road monitors (U.S. Environmental Protection Agency, 2011a).
- "Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas" – provides guidance on hot-spot analyses for $PM_{2.5}$ and PM_{10} and has applicable guidance relevant to NO_2[7] (U.S. Environmental Protection Agency, 2010b, e).

The following sections refer to the relevant sections of Appendix W and other existing guidance with summaries as necessary. Please refer to those original guidance documents for full discussion and consult with the appropriate EPA Regional Modeling Contact if questions arise about interpretation on modeling techniques and procedures[8].

C.3 Model Selection

Preferred air quality models for use in regulatory applications are addressed in Appendix A of EPA's *Guideline on Air Quality Models*. If a model is to be used for a particular application,

[6] The Support Center for Regulatory Atmospheric Modeling (SCRAM) website is available at: http://www.epa.gov/ttn/scram/

[7] Hereafter referred to as "PM hot-spot guidance."

[8] List of regional modeling contacts by EPA Regional Office is available from SCRAM website at: http://www.epa.gov/ttn/scram/guidance_cont_regions.

the user should follow the guidance on the preferred model for that application. These models may be used without an area specific formal demonstration of applicability as long as they are used as indicated in each model summary of Appendix A. Further recommendations for the application of these models to specific source problems are found in subsequent sections of Appendix W. In 2005, EPA promulgated the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) as the Agency's preferred near-field dispersion modeling for a wide range of regulatory applications in all types of terrain based on extensive developmental and performance evaluation.

As described in the PM hot-spot guidance (U.S. Environmental Protection Agency, 2010b, e), two dispersion models have been recommended for use in the PM hot-spot analyses and are applicable as well to NO_2 modeling: EPA's preferred near-field dispersion model, AERMOD (U.S. Environmental Protection Agency, 2004a, 2011b) and CAL3QHCR (Eckhoff and Braverman, 1995).

For most scenarios to be considered as part of this TAD, AERMOD should be used. AERMOD was used in the NO_2 Risk and Exposure Assessment (U.S. Environmental Protection Agency, 2008a) and performed generally well and is the recommended model for most mobile source modeling scenarios.[9] The guidance discussed here focuses on the use of AERMOD for mobile source modeling.

The AERMOD modeling system includes several components, which fall into one of two categories: regulatory and non-regulatory. The regulatory components are:

---

[9] For example, EPA cites AERMOD as a recommended model when completing PM hot-spot analyses for transportation conformity purposes. See Section 7.3 of EPA's PM hot-spot guidance (U.S. EPA, 2010b).

- AERMOD: the dispersion model (U.S. Environmental Protection Agency, 2004a, 2011b)
- AERMAP: the terrain processor for AERMOD (U.S. Environmental Protection Agency, 2011c, 2004b)
- AERMET: the meteorological data processor for AERMOD (U.S. Environmental Protection Agency, 2004c, 2011d)

The non-regulatory components are:

- AERSURFACE: the surface characteristics processor for AERMET (U.S. Environmental Protection Agency, 2008b)
- AERSCREEN: a recently released screening version of AERMOD (U.S. Environmental Protection Agency, 2011e)
- BPIPPRIME: the building input processor (U.S. EPA, 2004d)

Before running AERMOD, the user should become familiar with the user's guides associated with the modeling components listed above and the AERMOD Implementation Guide (AIG) (U.S. Environmental Protection Agency, 2009)The AIG lists several recommendations for applications of AERMOD which would be applicable for NO_2 roadway modeling.

C.4 Receptor Placement

The receptor grid is unique to the particular situation and depends on the size of the modeling domain, number of modeled sources, and complexity of terrain. Receptors should be placed in areas that are considered ambient air. Receptor placement should be of sufficient density to provide resolution needed to detect significant gradients in the concentrations with receptors placed closer together near the source to detect local gradients and placed farther apart away from the source. In addition, the user should place receptors at key locations such as around facility fence lines (which define the ambient air boundary for a particular source) or monitor locations (for comparison to monitored concentrations for model evaluation purposes). Generally, the receptor network should cover the modeling domain. However, for the purpose of the modeling discussed in this Technical Assistance Document, receptors may not have to be placed throughout the domain, but only near the roadways, i.e., receptors may not be placed out to one or five kilometers from the roadways for road comparison purposes in an effort to identify or aid in the identification of candidate near-road monitoring sites. Refer to Section 7.6 of the PM hot-spot guidance for additional guidance on placing receptors near roadways and the AERMOD User's Guide and Addendum for receptor inputs into AERMOD. Receptors may also be placed in locations that may represent potential monitoring sites as outlined in Section 6 of this document.

C.5 OLM and PVMRM

As outlined in Section 5.2.4 of Appendix W, there is a three-tiered approach to estimating NO_2 concentrations from AERMOD. The first tier, the most conservative, is to assume total conversion of NO to NO_2. The second, less conservative tier is to apply a representative equilibrium NO_2/NO_x ratio to modeled concentrations to yield NO_2 concentrations. The third tier is to use a detailed analysis on a case-by-case basis, using PVMRM (Hanrahan, 1999a, b; Cimorelli et al., 2004) or OLM. In the March 1, 2011, memorandum "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard," clarification was provided for tiers 2 and 3. A summary is provided here but users are strongly encouraged to read the memorandum for details. For modeling of mobile NOx emissions, it is expected that the tier 3 approach would be implemented to account for the chemical transformations from NOx to NO_2 and not treat NOx as an inert pollutant.

For the tier 3 approach, either PVMRM or OLM, the March 1, 2011 memorandum gave clarification about their use. The clarifications are summarized in Section 10.2.1, but again the user is strongly encouraged to read the March 1, 2011 memorandum in full as well as consult the AERMOD User's Guide (U.S. Environmental Protection Agency, 2004a) and addendum (U.S.

Environmental Protection Agency, 2011b) for details about the implementation of PVMRM and OLM in AERMOD.

C.5.1 Source Characterization

As described in the Appendix J of the PM hot-spot guidance (U.S. EPA, 2010c), road segments can be characterized as either elongated area sources (AERMOD source type AREA) or a series of volume sources (AERMOD source type VOLUME). Refer to that appendix for more information about these source characterizations and their use in near-roadway modeling. For general information about these source types, refer to the AERMOD User's Guide and addendum (U.S. EPA, 2004a; U.S. EPA, 2011b). As noted in Section 10.2.1 of the TAD, if modeling roadway segments with PVMRM, it is recommended to represent the roadway as a series of volume sources.

C.5.2 Inclusion of Nearby Sources

The inclusion of stationary sources or other nearby mobile sources in modeling of NO_x mobile emissions should be considered carefully and is complicated given the nature of the pollutant, the form of the NO_2 NAAQS standard, and the purpose of the modeling. Sometimes, moderate or large stationary sources or other major roadways may be located within a few kilometers of a targeted major roadway. Inclusion of other sources in mobile source modeling may heavily influence the near-road environment and change the spatial distribution and magnitude of modeled concentrations and are discussed below.

If road segments are modeled without any consideration of nearby sources, the modeled peak concentrations will usually be near the road segments. If road segments are modeled as elongated areas sources, the maximum concentration will often occur near the ends of segments as the wind blows along the source. However, if other sources are included in the modeling results, and the sources are sufficiently large enough, the peak concentrations' locations may shift toward those sources away from the roads of interest, thus impacting the decision on near-road monitor sites. Also, those sources could influence the near-road environment and any monitor placed near the road may measure influences from those sources.

Another implication of inclusion or non-inclusion of other sources in the modeling is in the application of PVMRM or OLM to model NO to NO_2 conversion in AERMOD. If the other sources are included in the same model run with the road segment sources of interest, there are more sources to compete for the input ozone to convert NO to NO_2. The additional sources can lead to a different final result than if they were not included in the model run.

A recommendation is to model the road segment or segments of interest along with any nearby sources that may influence the near-road environment around the road segment(s) of interest and model with the OLM option with OLMGROUP ALL. For model output, create multiple source groups with the SRCGROUP keyword and output design values for each source group to analyze the effects of the other sources. Note, that the grouping of sources for SRCGROUP is independent of the grouping for OLM (see Section 2.5.5 of the AERMOD User's Guide Addendum (U.S. EPA, 2011b)).

For example, if an area contains a road segment of interest and three stationary sources are nearby, then all sources can be modeled with OLM and using the OLMGROUP ALL option. Two source groups can be created: 1) a source group for the road segment only, and 2) a source group representing contributions from all sources (SRCGROUP ALL). The user can then output concentrations for design values for the road only source group and values for the total source group (See Section D.9 for output options for design value calculations).

The user can then analyze those results to see the effects of the stationary sources near the roadway and use that information to inform the monitor siting decision or inform the peak concentration analysis. The user can use design values based on the road segment to refine the monitor siting location.

C.5.3 Urban/Rural Classification

For any dispersion modeling exercise, the urban or rural determination of a source is important in determining the boundary layer characteristics that affect the model's prediction of downwind concentrations. **Figure C-1** gives example maximum 1-hour concentration profiles within 100 meters for a road segment represented by an area source (Figure C-1a) and a volume source (Figure C-1b) based on urban vs. rural designation. The urban population used for the examples is 100,000. For both cases, the urban concentrations are much less than the rural concentrations. These profiles show that the urban or rural designation of a source can be quite important.

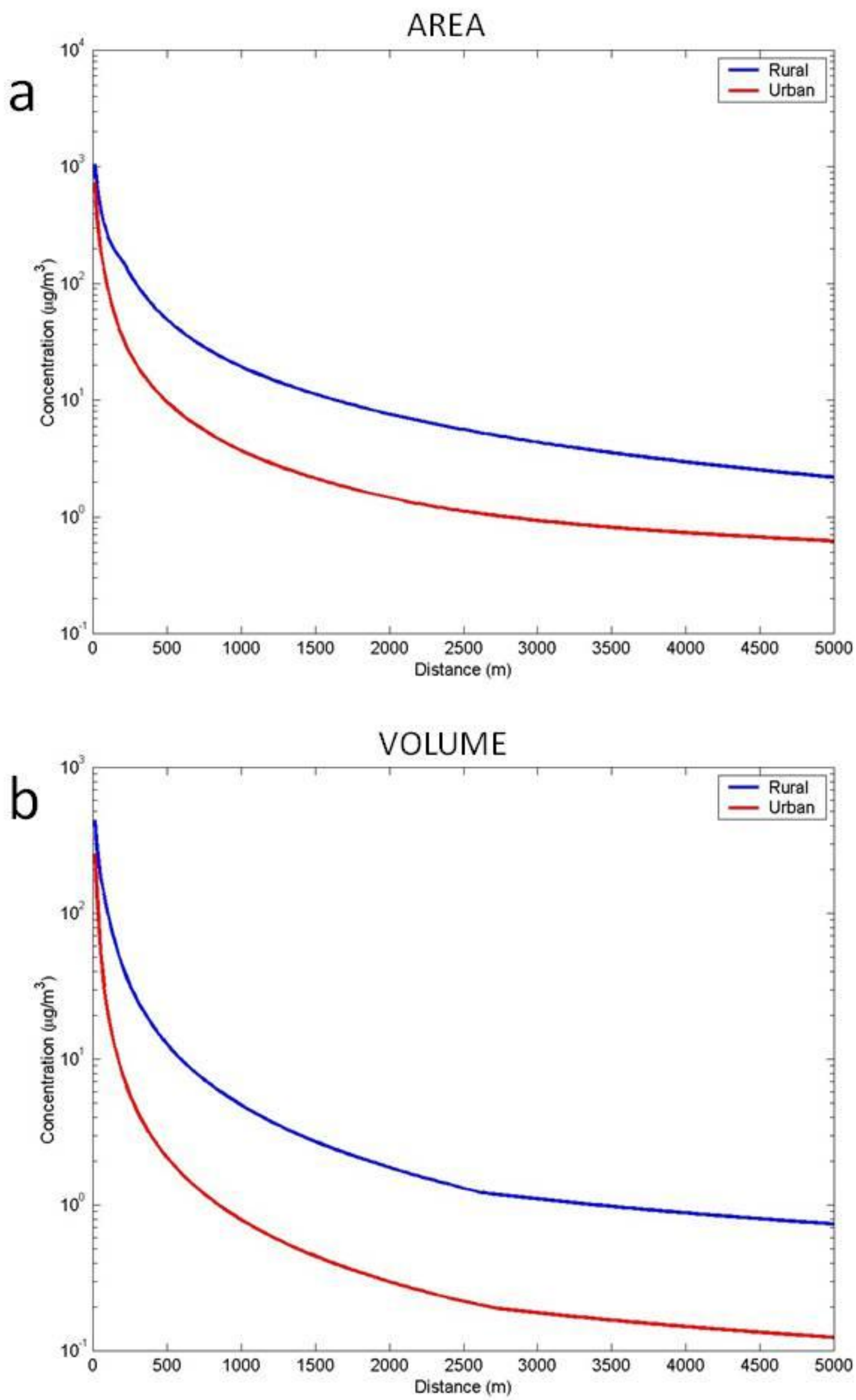

Figure C-1. Urban (red) and rural (blue) concentration profiles for (a) area source release, and (b) volume source release.

Determining whether a source is urban or rural can be done using the methodology outlined in Section 7.2.3 of Appendix W and recommendations outlined in Sections 5.1 through 5.3 in the AIG (U.S. Environmental Protection Agency, 2009). In summary, there are two methods of urban/rural classification described in Section 7.2.3 of Appendix W.

- The first method of urban determination is a land use method (Appendix W, Section 7.2.3c). In the land use method, the user analyzes the land use within a 3 km radius of the source using the meteorological land use scheme described by Auer (1978). Using this methodology, a source is considered urban if the land use types—I1 (heavy industrial), I2 (light-moderate industrial), C1 (commercial), R2 (common residential), and R3 (compact residential)—are 50% or more of the area within the 3 km radius circle. Otherwise, the source is considered a rural source.
- The second method uses population density and is described in Section 7.2.3d of Appendix W. As with the land use method, a circle of 3 km radius is used. If the population density within the circle is greater than 750 people/km^2, then the source is considered urban. Otherwise, the source is modeled as a rural source. Of the two methods, the land use method is considered more definitive (Section 7.2.3e, Appendix W).

Caution should be exercised with either classification method. As stated in Section 5.1 of the AIG (U.S. Environmental Protection Agency, 2009), when using the land use method, a source may be in an urban area but located close enough to a body of water or other non-urban land use category to result in an erroneous rural classification for the source. The AIG in Section 5.1 cautions users against using the land use scheme on a source by source basis, but advises considering the potential for urban heat island influences across the full modeling domain.

When using the population density method, Section 7.2.3e of Appendix W states, "Population density should be used with caution and should not be applied to highly industrialized areas where the population density may be low and thus a rural classification would be indicated, but the area is sufficiently built-up so that the urban land use criteria would be satisfied..." With either method, Section 7.2.3(f) of Appendix W recommends modeling all sources within an urban complex as urban, even if some sources within the complex would be considered rural using either the land use or population density method.

Another consideration that may need attention is when the user is including stationary sources in the modeling exercise (which is discussed in Section 5.1 of the AIG, regarding tall stacks located within or adjacent to small- to moderate-size urban areas). In such cases, the stack height or effective plume height for very buoyant sources may extend above the urban boundary layer height. The application of the urban option in AERMOD for these types of sources may artificially limit the plume height. The use of the urban option may not be appropriate for these sources, since the actual plume is likely to be transported over the urban boundary layer. Section 5.1 of the AIG gives details on determining if a tall stack should be modeled as urban or rural, based on comparing the stack or effective plume height to the urban boundary layer height and equation 104 of the AERMOD formulation document (Cimorelli et al., 2004). This equation is:

$$z_{iuc} = z_{iuo}\left(\frac{P}{P_o}\right)^{1/4} \qquad \textbf{(D-1)}$$

where z_{iuo} is a reference height of 400 m corresponding to a reference population P_o of 2,000,000 people.

If a stack is a buoyant release, the plume may extend above the urban boundary layer and may be best characterized as a rural source, even if it were near an urban complex. Exclusion of these elevated sources from application of the urban option would need to be justified on a case-by-case basis in consultation with the appropriate reviewing authority.

AERMOD requires the input of urban population when utilizing the urban option. Population can be entered to one or two significant digits (i.e., an urban population of 1,674,365 can be entered as 1,700,000). Users can enter multiple urban areas and populations using the URBANOPT keyword in the runstream file (U.S. Environmental Protection Agency, 2004a, 2011b). If multiple urban areas are entered, AERMOD requires that each urban source be associated with a particular urban area or AERMOD model calculations will abort. Urban populations can be determined by using a method described in Section 5.2 of the AIG (U.S. Environmental Protection Agency, 2009).

C.6 Meteorological Inputs

Section C.7 gives guidance on the selection of meteorological data for input into AERMOD. Much of the guidance from Section 8.3 of Appendix W is applicable to NO_2 near-road modeling and is summarized here. In Section C.7.2.1, the use of a new tool, AERMINUTE (U.S. Environmental Protection Agency, 2011f), is introduced. AERMINUTE is an AERMET pre-processor that calculates hourly averaged winds from ASOS (Automated Surface Observing System) 1-minute winds.

C.6.1 Surface Characteristics and Representativeness

The selection of meteorological data that are input into a dispersion model should be considered carefully. The selection of data should be based on spatial and climatological (temporal) representativeness (Appendix W, Section 8.3). The representativeness of the data is based on the following:

1) the proximity of the meteorological monitoring site to the area under consideration,

2) the complexity of terrain,

3) the exposure of the meteorological site, and

4) the period of time during which data are collected.

Sources of meteorological data are National Weather Service (NWS) stations, site-specific or onsite data, and other sources, such as universities, Federal Aviation Administration (FAA), military stations. Appendix W addresses spatial representativeness issues in Sections 8.3.a and 8.3.c.

Spatial representativeness of the meteorological data can be adversely affected by large distances between the source and receptors of interest and the complex topographic characteristics of the area (Appendix W, Section 8.3.a and 8.3.c). If the modeling domain is large enough such that conditions vary drastically across the domain then the selection of a single station to represent the domain should be carefully considered. Also, care should be taken when selecting a station if the area has complex terrain. While a source and meteorological station may be geographically close, if there is complex terrain between them, conditions at the meteorological station may not be representative of the source. An example would be a source located on the windward side of a mountain chain with a meteorological station a few kilometers away on the leeward side of the mountain.

Spatial representativeness for offsite data should also be assessed by comparing the surface characteristics (albedo, Bowen ratio, and surface roughness) of the meteorological monitoring site and the analysis area. When processing meteorological data in AERMET (U.S. Environmental Protection Agency, 2004c, 2011d) the surface characteristics of the meteorological site should be used [Section 8.3.c of Appendix W and the AERSURFACE User's Guide (U.S. Environmental Protection Agency, 2008b)]. Spatial representativeness should also be addressed for each meteorological variable separately. For example, temperature data from a meteorological station several kilometers from the analysis area may be considered adequately representative, while it may be necessary to collect wind data near the plume height (Section 8.3.c of Appendix W).

Surface characteristics can be calculated in several ways. For details see Section 3.1.2 of the AIG (U.S. Environmental Protection Agency, 2009). EPA has developed a tool, AERSURFACE (U.S. Environmental Protection Agency, 2008b) to aid in the determination of surface characteristics. The current version of AERSURFACE uses 1992 National Land Cover Data. Note that the use of AERSURFACE is not a regulatory requirement but the methodology outlined in Section 3.1.2 of the AIG should be followed unless an alternative method can be justified.

C.6.2 Meteorological Inputs

Appendix W states in Section 8.3.1.1 that the user should acquire enough meteorological data to ensure that worst-case conditions are adequately represented in the model results. Appendix W states that 5 years of NWS meteorological data or at least one year of site-specific data should be used (Section 8.3.1.2, Appendix W) and should be adequately representative of the study area. If one or more years (including partial years) of site-specific data are available, those data are preferred.

While the form of the NO_2 NAAQS contemplates obtaining three years of monitoring data, this does not preempt the use of 5 years of NWS data or at least one year of site-specific data in the modeling. The 5-year average based on the use of NWS data, or an average across one or more years of available site specific data, serves as an unbiased estimate of the 3-year average for purposes of modeling demonstrations of compliance with the NAAQS (see the June 28, 2010, Clarification Memorandum on "Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" (U.S. Environmental Protection Agency, 2010d)). See the memorandum for more details on the use of 5 years of NWS data or at least one year of site-specific data and applicability to the NAAQS.

C.6.2.1 NWS Data

NWS data are available from the National Climatic Data Center (NCDC) in many formats, with the most common one in recent years being the Integrated Surface Hourly data (ISH). Most available formats can be processed by AERMET. As stated in Section C.7.1, when using data from an NWS station alone or with site-specific data, the data should be spatially and temporally representative of conditions at the modeled sources.

A recently discovered issue with ASOS is that 5-second wind data that are used to calculate the 2-minute average winds are truncated rather than rounded to whole knots. For example, a wind of 2.9 knots is reported as 2 knots, not 3 knots. To account for this truncation of NWS winds (either standard observation or AERMINUTE output), an adjustment of ½ knot or 0.26 m/s is added to the winds in stage 3 AERMET processing. For more details, refer to the AERMET User's Guide Addendum (U.S. Environmental Protection Agency, 2011d) and/or the appropriate EPA Regional Modeling Contact.

C.6.2.2 AERMINUTE

In AERMOD, concentrations are not calculated for variable wind (i.e., missing wind direction) and calm conditions, resulting in zero concentrations for those hours. Since the NO_2 NAAQS is a one hour standard, these light wind conditions may be the controlling meteorological circumstances in some cases because of the limited dilution that occurs under low wind speeds which can lead to higher concentrations. The exclusion of a greater number of instances of near-calm conditions from the modeled concentration distribution may therefore lead to underestimation of daily maximum 1-hour concentrations for calculation of the design value.

To address the issues of calm and variable winds associated with the use of NWS meteorological data, EPA has developed a preprocessor to AERMET, called AERMINUTE (U.S. Environmental Protection Agency, 2011f) that can read 2-minute ASOS winds and calculate an hourly average. Beginning with year 2000 data, NCDC has made the 1-minute wind data, reported every minute from the ASOS network, freely available. The AERMINUTE program reads these 2-minute winds and calculates an hourly average wind. In AERMET, these hourly averaged winds replace the standard observation time winds obtained from the archive of meteorological data. This approach results in a lower number of calms and missing winds and an increase in the number of hours used in averaging concentrations. For more details regarding the use of NWS data in regulatory applications see Section 8.3.2 of Appendix W and for more information about the processing of NWS data in AERMET and AERMINUTE, see the AERMET (U.S. Environmental Protection Agency, 2004c, 2011d) and AERMINUTE User's Guides (U.S. Environmental Protection Agency, 2011f).

C.6.2.3 Site-Specific Data

The use of site-specific meteorological data is the best way to achieve spatial representativeness in the modeling. AERMET can process a variety of formats and variables for site-specific data. The use of site-specific data for regulatory applications is discussed in detail in Section 8.3.3 of Appendix W. Due to the range of data that can be collected onsite and the range of formats of data input to AERMET, the user should consult Appendix W, the AERMET User's Guide (U.S. Environmental Protection Agency, 2004c, 2011d), and Meteorological Monitoring Guidance for Regulatory Modeling Applications (U.S. Environmental Protection Agency, 2000). Also, when processing site-specific data for an urban application, Section 3.3 of the AERMOD Implementation Guide offers recommendations for data processing. In summary, the guide recommends that site-specific turbulence measurements should not be used when applying AERMOD's urban option, in order to avoid double counting the effects of enhanced turbulence due to the urban heat island.

C.6.2.4 Upper-Air Data

AERMET requires full upper air soundings to calculate the convective mixing height. For AERMOD applications in the U.S., the early morning sounding, usually the 1200 UTC (Universal Time Coordinate) sounding, is typically used for this purpose. Upper air soundings can be obtained from the Radiosonde Data of North America CD for the period 1946-1997. Upper air soundings for 1994 through the present are also available for free download from the Radiosonde Database Access website. Users should choose all levels or mandatory and significant pressure levels[10] when selecting upper air data. Selecting mandatory levels only would not be adequate for input into AERMET as the use of just mandatory levels would not provide an adequate characterization of the potential temperature profile.

C.7 Background Concentrations

Background concentrations are often included in a modeling analysis to account for sources not explicitly modeled or natural sources. Given the nature of the modeling described in this document, either for comparing road segments or refining monitor locations, inclusion of background concentrations may not be necessary, but best professional judgment should be used. Section 8.2 of Appendix W gives more detailed general guidance regarding background concentrations. The March 1, 2011, memorandum also gives guidance specific to NO_2 and is summarized here:

- The June 28, 2010, memorandum initially discussed a “first tier” option of including the maximum 1-hour NO_2 concentration from a representative with the modeled design values. This option may be applied without further justification.
- The March 1, 2011, memorandum recognized that the above approach may be overly conservative and may be prone to reflecting source-oriented impacts from nearby sources, thus increasing chances of double counting.
- The March 1, 2011, memorandum discussed a second, less conservative form of application of a uniform background by using monitored design values from the most recent three years of monitor data.

[10] By international convention, mandatory levels are in millibars: 1,000, 850, 700, 500, 400, 300, 200, 150, 100, 50, 30, 20, 10,7 5, 3, 2, and 1. Significant levels may vary depending on the meteorological conditions at the upper-air station.

- Also discussed in the March 1, 2011, memorandum is the use of temporally varying background concentrations; i.e., using the 98th percentile of concentrations by season and hour of day. The memorandum also discussed including a day-of-week component to background concentrations for mobile sources.

The user is strongly encouraged to read the March 1, 2011, memorandum for full details about background concentrations.

For the purposes of the modeling discussed in this technical document, inclusion of background concentrations may not be necessary. If the purpose of the modeling is to compare relative impacts of road segments, including background concentrations may not be necessary, since the purpose of the modeling is not a cumulative impact analysis. However, if the purpose of the modeling is to inform monitor siting or identifying peaks, background concentrations should be included, as well as stationary sources (See Section D.6.4) in order to fully characterize the air quality situation.

C.8 Running AERMOD and Implications for Design Value Calculations

Recent enhancements to AERMOD include options to aid in the calculation of design values for comparison with the NO_2 NAAQS. These enhancements include:

- The output of daily maximum 1-hour concentrations by receptor for each day in the modeled period for a specified source group. This is the MAXDAILY output option in AERMOD.

- The output, for each rank specified on the RECTABLE output keyword, of daily maximum 1-hour concentrations by receptor for each year for a specified source group. This is the MXDYBYYR output option.

- The MAXDCONT option, which shows the contribution of each source group to the high ranked values for a specified target source group, paired in time and space. The user can specify a range of ranks to analyze, or specify an upper bound rank (i.e., 8th highest) and a lower threshold value (such as the NAAQS) for the target source group. The model will process each rank within the range specified, but will stop after the first rank (in descending order of concentration) that is below the threshold, specified by the user. A warning message will be generated if the threshold is not reached within the range of ranks analyzed (based on the range of ranks specified on the RECTABLE keyword). For more details about the enhancements, see the AERMOD User's guide Addendum (U.S. Environmental Protection Agency, 2011c).

C.9 References

Auer Jr. A.H. (1978) Correlation of land use and cover with meteorological anonalies. *J. Applied Met.* **17**, 636-643.

Cimorelli A.J., Perry S.G., Venkatram A., Weil J.C., Paine R.J., Wilson R.B., Lee R.F., Peters W.D., Brode R.W., and Paumier J.O. (2004) AERMOD: description of model formulation. Report by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Research Triangle Park, NC, EPA-454/R-03-004, September. Available on the Internet at http://www.epa.gov/scram001/7thconf/aermod/aermod_mfd.pdf.

Eckhoff P.A. and Braverman T.N. (1995) Addendum to the user's guide to CAL3QHC version 2.0 (CAL3QHCR user's guide). the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Technical Support Division, Research Triangle Park, NC, September. Available on the Internet at http://www.weblakes.com/products/calroads/resources/docs/CAL3QHC.pdf.

Hanrahan P.L. (1999a) The plume volume molar ratio method for determining NO_2/NO_x ratios in modeling - part I: methodology. *J. Air Waste Manage. Assoc.* **49**, 1324-1331.

Hanrahan P.L. (1999b) The plume volume molar ratio method for determining NO2/NOx ratios in modeling - part II: evaluation studies. *J. Air Waste Manage. Assoc.* **49**, 1332-1338.

U. S. Environmental Protection Agency (2005) Revision to the guideline on air quality models: adoption of a preferred general purpose (flat and complex terrain) dispersion model and other revisions; Final Rule (40 CFR Part 51). *Fed. Regist.* **70**. Available on the Internet at http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf.

U.S. Environmental Protection Agency (1993) Guideline on air quality models (revised), including Supplements A and B. by U.S. Environmental Protection Agency, Research

Triangle Park, NC, (See also 40 CFR Part 51 Appendix W), EPA-450/2-78-027R, July 20.

U.S. Environmental Protection Agency (2000) Meteorological monitoring guidance for regulatory modeling applications. Office of Air Quality Planning and Standards, Research Triangle Park, NC, Document EPA-454/R-99-005, February. Available on the Internet at http://www.epa.gov/scram001/guidance/met/mmgrma.pdf.

U.S. Environmental Protection Agency (2004a) User's guide for the AMS/EPA regulatory model (AERMOD). Prepared by the Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/B-03-001, September.

U.S. Environmental Protection Agency (2004b) Users guide for the AERMOD terrain preprocessor (AERMAP). EPA-454/B-03-003, October. Available on the Internet at http://www.epa.gov/scram001/7thconf/aermod/aermapugb2.pdf.

U.S. Environmental Protection Agency (2004c) User's guide for the AERMOD meteorological preprocessor (AERMET). Prepared by the Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/B-03-002, November.

U.S. Environmental Protection Agency (2004d) User's guide to the building profile input program, revised. Prepared by the Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-93-038, April 21. Available on the Internet at http://www.epa.gov/scram001/userg/relat/bpipdup.pdf.

U.S. Environmental Protection Agency (2008a) Risk and exposure assessment to support the review of the NO_2 primary National Ambient Air Quality Standard. Report, EPA-452/R-08-008a, November. Available on the Internet at http://www.epa.gov/ttnnaaqs/standards/nox/data/20081121_NO2_REA_final.pdf.

U.S. Environmental Protection Agency (2008b) AERSURFACE user's guide. EPA-454/B-08-001, January. Available on the Internet at http://www.epa.gov/ttn/scram/7thconf/aermod/aersurface_userguide.pdf.

U.S. Environmental Protection Agency (2009) AERMOD implementation guide. Office of Air Quality Planning and Standards, Research Triangle Park, NC, March 19.

U.S. Environmental Protection Agency (2010a) Motor vehicle emission simulator (MOVES) user guide for MOVES2010a User guide, EPA-420-B-10-036, August. Available on the Internet at http://www.epa.gov/otaq/models/moves/MOVES2010a/420b10036.pdf; additional resources are available at http://www.epa.gov/otaq/models/moves/index.htm.

U.S. Environmental Protection Agency (2010b) Transportation conformity guidance for quantitative hot-spot analyses in $PM_{2.5}$ and PM_{10} nonattainment and maintenance areas. Guidance document prepared by the Transportation and Regional Programs Division, Office of Transportation and Air Quality, EPA-420-B-10-040, December. Available on the Internet at http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040.pdf.

U.S. Environmental Protection Agency (2010c) Using MOVES in project-level carbon monoxide analyses. Report by the Transportation and Regional Programs Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-420-B-10-041, December. Available on the Internet at http://www.epa.gov/otaq/stateresources/transconf/policy/420b10041.pdf.

U.S. Environmental Protection Agency (2010d) Applicability of Appendix W modeling guidance for the 1-hour NO2 National Ambient Air Quality Standard. Tyler Fox technical memorandum Research Triangle Park, NC, June 28. Available on the Internet at http://www.epa.gov/ttn/scram/ClarificationMemo_AppendixW_Hourly-NO2-NAAQS_FINAL_06-28-2010.pdf.

U.S. Environmental Protection Agency (2010e) Transportation conformity guidance for quantitative hot-spot analyses in $PM_{2.5}$ and PM_{10} nonattainment and maintenance areas: Appendices. Guidance document prepared by the Transportation and Regional Programs Division, Office of Transportation and Air Quality, EPA-420-B-10-040, December. Available on the Internet at http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040-appx.pdf.

U.S. Environmental Protection Agency (2011a) Additional clarification regarding application of Appendix W modeling guidance for the 1-hour NO_2 National Ambient Air Quality Standard. Tyler Fox memorandum Research Triangle Park, NC, March 1,. Available on the Internet at http://www.epa.gov/ttn/scram/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf.

U.S. Environmental Protection Agency (2011b) Addendum to user's guide for the AMS/EPA regulatory model - AERMOD. Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/B-03-001, February.

U.S. Environmental Protection Agency (2011c) Addendum: users guide for the AERMOD terrain preprocessor (AERMAP). EPA-454/B-03-003, March. Available on the Internet at http://www.epa.gov/ttn/scram/models/aermod/aermap/aermap_userguide.zip.

U.S. Environmental Protection Agency (2011d) Addendum: users guide for the AERMOD meteorological preprocessor (AERMET). EPA-454/B-03-002, February. Available on the Internet at http://www.epa.gov/ttn/scram/7thconf/aermod/aermet_userguide.zip.

U.S. Environmental Protection Agency (2011e) AERSCREEN user's guide. EPA-454/B-11-001, March. Available on the Internet at http://www.epa.gov/ttn/scram/models/screen/aerscreen_userguide.pdf.

U.S. Environmental Protection Agency (2011f) AERMINUTE user's instructions (draft). User's guide. Available on the Internet at http://www.epa.gov/ttn/scram/models/screen/aerscreen_userguide.pdf.